CENTRAL REGION LIMNOLOGY
2000 ANNUAL REPORT OF PROGRESS

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Edmundson, J. A., V. P. Litchfield, J. M. Edmundson, G. L. Todd, and L. Brannian. 2000. Central Region Limnology 2000 annual report of progress. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report No. 2A00-27:25p.

The Alaska Department of Fish and Game (ADF&G), Central Region Limnology (CRL) program provides technical support for research activities in upper and lower Cook Inlet, Bristol Bay, and Prince William Sound areas including fish stock assessment, aquatic resource surveys, ecological studies, nutrient enrichment, and fry stocking. A key component of this program is the integration of ecological data with fisheries information to assess carrying capacity of aquatic systems and to develop models that improve management of future fish stocks. In addition, CRL laboratory provides technical support of various fisheries and limnological projects with other state, federal, and non-profit aquaculture associations. An overview of program organization and field and laboratory research highlights over the past fiscal year 2000 is presented. This report is also designed to provide results of CRL's annual quality control and quality assurance program, statistical evaluations of analytical methodologies, and updated field and laboratory methods, in order to promote regional as well as statewide standardization and consistency in methods for assessing aquatic production.

INTRODUCTION

In 1998 staff and funding of the Alaska Department of Fish and Game statewide limnology program (McNair 1996) were formally re-organized and transferred from the Commercial Fisheries Division (CFD) Headquarters in Juneau to CFD Region II (Central) in Anchorage as Central Region Limnology (CRL). The desired outcome of CRL is to advance fishery and aquatic science through developing research information (analytical results) and conducting fisheries research activities in upper and lower Cook Inlet, Prince William Sound, and Bristol Bay areas. Research activities include fisheries monitoring, stock assessments, aquatic resource surveys, biological investigations, and limnological evaluations. Reflecting on the objectives within CRL, the current mission statement is as follows:

The overall mission of the Commercial Fisheries Division's Central Region Limnology is to (1) integrate ecological data to assess sustainability of commercial salmon production and (2) provide technical support of projects related to management and development of commercial fishery stocks and to promote aquatic resource conservation. The laboratory analyzes water and biological samples collected from lake and riverine systems on a contractual basis with state, federal, and private non-profit agencies for projects involving the evaluation of salmon escapement goals, assessment of aquatic productivity, and enhancement activities. Technical support for non-region projects are prioritized based on applicability to commercial fishery management needs, continuance of long-term data sets, administrative demands and funding.

In keeping with the above mission statement, CRL projects within Region II receive top priority. After fulfilling regional research and management needs, CRL also develops contracts for processing samples for non-region projects provided they meet specific criteria. First, CRL accepts projects in which the scientific information can be used to develop techniques and models to assess fisheries production. We encourage data sharing and cooperative projects that elucidate major factors, processes, and underlying mechanisms regulating fish production. To that end, water or biological samples to be analyzed by CRL must be collected using standardized procedures detailed in our field and laboratory manual (Koenings et al. 1987). Second, applied limnological and ecological concepts toward developing integrated salmon production models can require the collection of data over many years. For example, the dependence of juvenile salmon production on lake/riverine physical characteristics, forage availability, and density-dependent factors argues for including ecological data in stock-recruit modeling. Such an approach may lead to improvements in the ability to forecast fish stocks. As such, CRL continues to provide technical support for projects with significant and long-term data sets. On the other hand, CRL does not develop or accept new projects in areas where the information obtained is unrelated to the missions of CFD and CRL. Third, because of the cumulative time and cost for developing multiple cooperative agreements and budget tracking, CRL prefers that all administrative functions associated with initiating and implementing cooperative projects in other regions be handled by ADF&G personnel within their respective area/region. Fourth, cooperative agreements must meet a minimum funding level to cover all direct and indirect costs based on the current laboratory fee schedule.

Our objective in this report is to provide a summary of recent research accomplishments and overall program direction (status) of CRL. In addition, our annual report serves as a conveyance of addendum or errata associated with refinement of methods or development of new technology or analyses. We also include results of our annual laboratory quality control and assurance program and provide an annual water quality sample inventory for fiscal year 2000. This report is the first annual report of progress and we hope program reviewers will find it helpful in assessing fisheries research within central region.

PROGRAM ORGANIZATION

CRL is under the responsibility of the Upper and Lower Cook Inlet Regional Management Biologist. The existing research program has two permanent staff members including project leader and six long-term seasonal biologists and technicians (Figure 1). The project leader or principal investigator oversees all regional CRL staff and projects dealing with fisheries stock assessment, fish stocking, nutrient enrichment, and water-quality monitoring. CRL staff provides technical support for such projects and they participate in cooperative projects with state and federal agencies, non-profit aquaculture associations, universities, and public resource awareness groups. CRL operates a centralized laboratory in Soldotna where water chemistry, nutrients, plankton, and fish samples are sent from around Region II and elsewhere in the State to be processed and analyzed. For fiscal year (FY) 2000, CRL received $91,000 (22%) in general funds and $323,000 (78%) in total program receipts from other State and federal agencies, non-profit associations, and the *Exxon Valdez* Oil Spill (EVOS) trustee council (Table 1).

RESEARCH HIGHLIGHTS

Program highlights in the past year include fisheries research (field sampling by CRL personnel) directed toward (1) determining the depensatory mechanism(s) that cause or maintain the cycles in sockeye production of the Kvichak (Lake Iliamna) system stock, (2) assessing the productivity (rearing habitat) of sockeye salmon stocks of Skilak and Crescent lakes (upper Cook Inlet), (3) juvenile sockeye assessment related to stocking of Solf Lake (Prince William Sound, (4) water-quality monitoring of the Kenai River (upper Cook Inlet), and (5) technical support (laboratory analysis of samples by CRL personnel) of various fisheries and limnological projects throughout Region II, as well as in other areas of the State. The following is a brief overview of each of the projects.

Juvenile Sockeye Salmon Assessment and Limnological Studies of Lake Iliamna

This three-year project was funded by U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NA96FW0196) in response to the recent (1997-1998) poor returns of sockeye salmon in western Alaska. This project is a joint

CENTRAL REGION LIMNOLOGY

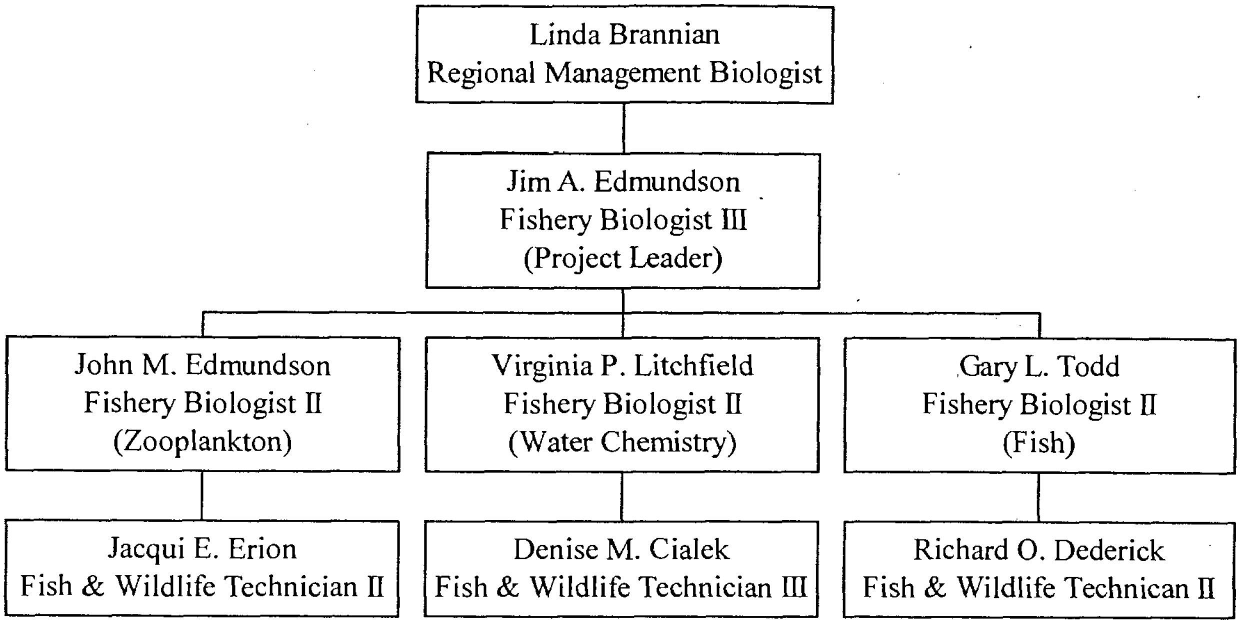

Figure 1. Organizational chart for Central Region Limnology, fiscal year 2000.

Table 1. Funding category, amount, and percentage of the total fiscal year 2000 budget including general funds and program receipts for Central Region Limnology.

Source	Amount (thousands)	Percentage (%)
General Fund Allocation	$91.0	22.0
State (pass through)	$64.8	15.6
Federal	$151.6	36.6
Private non-profit	$55.7	13.5
EVOS	$51.0	12.3
TOTAL	$414.1	100.0

venture among CRL, University of Alaska Fairbanks (UAF), University of Washington (UW), and National Marine Fisheries Service (NMFS). During FY 2000, many of the logistical problems involved with lake sampling and survey coverage of the largest lake in Alaska were resolved. A detailed project operational plan was subsequently prepared and adopted. Currently, the project is largely in the data collection phase. CRL is conducting regular (every 3 weeks during the open-water period) limnological surveys from multiple sites at Lake Iliamna to obtain both spatial and temporal information on underwater light and temperature regimes, water chemistry, nutrient concentrations, phytoplankton, zooplankton community structure and abundance, and fall fry size, condition, and age composition. We are also actively compiling and developing electronic databases containing historical limnological and fisheries data. This information will be used for a subsequent retrospective analysis to address the causes or maintenance of cycles in sockeye salmon production (adult returns). In addition, funding (via reimbursable services agreement) was approved for cooperating agencies to begin reconstruction of the fisheries paleolimnological record in Lake Iliamna by sediment core analysis (Finney 1998) and to develop a dynamic ecosystem (ECOPATH) (Christen and Pauley 1992) model of Lake Iliamna to explore the relationships between organisms in the lake. Lake sediment core samples have been collected and collection of representative samples of all lake biota for ECOPATH is also underway. Results of this project will be used to better understand sockeye production (i.e., carrying capacity) in the Kvichak system and to aid fishery managers in setting escapement goals so the stock can be optimally managed.

Assessment of Sockeye Salmon Productivity of Kenai and Crescent River Stocks

Research continued to evaluate lake-habitat characteristics relative to production of sockeye salmon in Skilak Lake, a major nursery lake of the Kenai River drainage and in Crescent Lake, which is a large sockeye producer on the west side of Cook Inlet. Limnological surveys were conducted approximately every 3-4 weeks during the open-water period (May-October) to collect information on environmental conditions (light, temperature, turbidity), nutrient (nitrogen and phosphorus) levels, primary production (chlorophyll), and zooplankton dynamics. Continued studies support the idea that there is selective cropping of copepods (zooplankton) by adjacent year classes of rearing sockeye juveniles that may cause a brood-year interaction (Schmidt et al. 1997), thus producing cycles in adult returns for the Kenai River (Skilak Lake) sockeye stock. In addition, information gathered on turbidity and light penetration suggests that the lower than expected production of sockeye from Crescent Lake in recent years is related to changing lake conditions. That is, increased turbidity and decreased light penetration coupled with relatively large escapements may have reduced the carrying capacity (zooplankton biomass) of the system. In 1999, the escapement goal was lowered to achieve an optimal balance between the current forage base and fry densities (Fried 1999). It is not known if the causal mechanism of higher turbidity is related to changes in the nature of the drainage pattern or other hydrologic phenomenon. However, turbidity fluctuations viewed on a decadal scale from Crescent Lake and nearby Skilak Lake suggest that turbidity levels may be increasing, perhaps brought about by a regional climatic shift. Continued studies to characterize the rearing conditions of these lakes will help assess or refine escapement goals for sockeye salmon in both systems in the context of changing environmental conditions and forage base resources.

Sockeye Salmon Stocking at Solf Lake

The sockeye salmon stocking project at Solf Lake is an EVOS funded restoration project aimed at developing a sockeye salmon run through the annual stocking of fry. The U.S. Forest Service is the principal investigator and CRL is the cooperating agency responsible for assessing juvenile sockeye production and collecting and analyzing limnological data. Approximately 100,000 sockeye fry were planted in Solf Lake each year since 1998. Preliminary results of the stocking program suggest that the stocked fry are not over-wintering in the lake, but are migrating from the system to sea soon after stocking. In addition, after two consecutive years of stocking, sockeye fry have reduced the forage base (zooplankton biomass) to a low level that could decrease freshwater growth and survival of subsequent stocked fry. Continued assessment of juvenile sockeye populations and collection of limnological data are essential to determine if the current stocking strategy is appropriate and if future stocking levels are optimally balanced with available food resources. Unfortunately, EVOS funding for continued juvenile sockeye assessment and the limnological work at Solf Lake beyond 30 September 2000 has been eliminated (EVOSTC 2000), though stocking continues.

Kenai River Water Quality Monitoring

The purpose of the Kenai River Citizen Water Quality Monitoring Project is to promote an awareness of citizen monitoring efforts and its use to assist the monitoring needs of the various agencies associated with the Kenai River. CRL personnel train volunteers in the proper technique for collecting water chemistry samples and benthic macroinvertebrates, which are used as water quality indicators. In addition, CRL provides laboratory analysis of both water and benthic invertebrate samples. The Kenai Watershed Forum, a natural resource awareness group, provides funding for CRL for fieldwork, volunteer training, and analysis of samples. Biological samples were collected from several sites in the Kenai River and associated tributaries and analyzed using a rapid assessment methodology. Because many benthic invertebrates are sensitive to physical and chemical changes in their aquatic habitat, the information being collected by this project may be useful in understanding potential or future naturally occurring or human-induced disturbances to the Kenai River system (Litchfield and Milner 1998).

Salmon Lake Sockeye Restoration

CRL provided technical assistance and expertise for an ongoing sockeye salmon restoration project at Salmon Lake (near the city of Nome), which was initially investigated in 1994 (Todd and Kyle 1996) and continues today. The lake system is unique in that it is the northernmost sockeye producing system in the State. This is a joint project with ADF&G, U.S. Bureau of Land Management (BLM) and Norton Sound Economic Development Corporation (NSEDC). CRL personnel assisted with smolt enumeration in the spring, hydroacoustic surveys of fry populations in the fall, and the CRL laboratory staff processed water and plankton samples. Lake enrichment continued during the 1999 growing season, the third year of a proposed five-year fertilizer program. Preliminary analytical results revealed there were positive responses in lower trophic level production to nutrient additions, and the 1999 adult salmon escapement into

Salmon Lake was estimated to be twice that of previously recorded escapements in to this lake. Thus, subsequent fry recruitment should benefit from a continuing nutrient enrichment program.

Laboratory Operations

In addition, to ADF&G's regional projects, CRL provided technical support for various State, federal, and private non-profit agencies (Table 2). During FY 2000, CRL laboratory staff processed more than 500 water and biological samples from 37 lakes and 6 streams (Table 3). These samples equate to a total of 15,000 individual analyses for all measured parameters.

CRL developed quality control charts (APHA 1998) to compute process variation for the most important analytes (Figures 2-8). Low and high range reference standards were analyzed and their measured concentration was then plotted with each run of samples. These charts include a center line which is the average concentration for the time being charted, upper and lower (or inner) warning levels, and upper and lower (or outer) control levels. We set warning levels at $\pm 2\sigma$ and control limits at $\pm 3\sigma$, where σ is the pooled standard deviation. Quality control outside these limits or a trend in the process statistic is evidence of special causes or unacceptable error in the analytical procedure. Out-of-control error includes, but is not limited to, improper equipment calibration or malfunction, inappropriate methods, calculation errors, or sample contamination. Corrective action is taken when the analyst deems the procedure out-of-control. Our quality control charts developed for sample runs over the past year revealed that the process statistics did not exceed the outer control limit and fell within the inner warning limits or within $\pm 1\sigma$. In addition, there was no apparent trend or pattern in tracking the reference samples (process statistic) suggesting random process error was in effect.

In addition to internal quality control measures, quality assurance of analytical results was maintained through our annual participation in the U.S. Geological Survey's analytical evaluation program for standard reference samples including trace constituents, major constituents, and low ionic strength nutrients. Laboratory determination of each analyte or constituent is rated on a scale from 4 to 0, based on the absolute *Z*-value, as listed below:

Performance Rating	Absolute *Z*-value
4 (excellent)	0.00 to 0.50
3 (good)	0.51 to 1.00
2 (satisfactory)	1.01 to 1.50
1 (marginal)	1.51 to 2.00
0 (unsatisfactory)	>2.00

Results of the 1999 program (Farrar 2000) indicated that for most constituents, our performance ratings were considered good to excellent (Table 4). However, our performance for nitrate determination was marginal even though the reported values seemed close to the most probable value, whereas for calcium and magnesium our performance rating was unsatisfactory. The larger than expected error for nitrate analysis was traced to a malfunction in an autoanalyzer module, which was subsequently corrected prior to processing samples. In addition, we

Table 2. Agencies and organizations contracting Central Region Limnology laboratory services, fiscal year 2000.

STATE
Alaska Department of Fish and Game, Commerical Fisheries Division (Region I)
Alaska Department of Fish and Game, Commercial Fisheries Division (Region IV)
Alaska Department of Fish and Game, Sport Fish Division (Anchorage)
Alaska Department of Environmental Conservation, Division of Water Quality Regulations (Anchorage)
Lake and Peninsula Borough
FEDERAL
U. S. Fish and Wildlife Service (King Salmon)
U. S. Forest Service (Girdwood)
U. S. Bureau of Land Management (Fairbanks)
PRIVATE NON-PROFIT
Cook Inlet Aquaculture Association
Kenai Watershed Forum
Kodiak Regional Aquaculture Association
Northern Southeast Regional Aquaculture Association
Southern Southeast Regional Aquaculture Association
Norton Sound Economic Development Corporation

Table 3. Inventory of water and biological samples processed (denoted "X") by Central Region Limnology laboratory, fiscal year 2000.

Water Body	Water Chemistry	Nutrients	Phytoplankton	Zooplankton	Benthos
Auke	-	-	X	-	-
Afognak	X	X	X	X	-
Anderson	X	X	X	-	-
Banner Creek	X	X	X	-	-
Bear	X	X	X	-	-
Beaver Creek	X	X	X	-	X
Becharof	X	X	X	X	-
Big Lake	X	X	X	-	-
Chilkat	X	X	X	X	-
Cooper	X	X	X	X	-
Cornelius	X	X	X	-	-
Cottonwood Creek	X	X	X	-	-
Cottonwood	X	X	X	-	-
Crescent	X	X	X	X	-
Deer	X	X	X	X	-
Delight	X	X	X	X	-
East Fork Moose Creek	X	X	-	-	X
Hazel	X	X	X	X	-
Hidden (Kenai)	X	X	X	X	-
Hidden (Kodiak)	X	X	X	X	-
Iliamna	X	X	X	X	-
Laura	X	X	X	X	-
Leisure	X	X	X	X	-
Little Kitoi	X	X	X	X	-
Malina	X	X	X	X	-
McDonald	X	X	X	X	-
Meadow Creek	X	X	X	X	-
Mud	X	X	X	-	-
Neklason	X	X	X	-	-
Orphea	X	X	X	X	-
Portage	X	X	X	X	-
Redoubt	-	-	X	-	-
Salmon	X	X	X	X	-
Skilak	X	X	X	X	-
Slikok Creek	X	X	-	-	X
Soldotna Creek	X	X	X	-	X
Solf	X	X	X	X	-

Table 3. (continued).

Water Body	Water Chemistry	Nutrients	Phytoplankton	Zooplankton	Benthos
Spiridon	X	X	X	X	-
Ugashik, Upper	X	X	X	X	-
Ugashik, Lower	X	X	X	X	-
Virginia	X	X	X	X	-
Wasilla	X	X	X	-	-
Waterfall	X	X	X	-	-

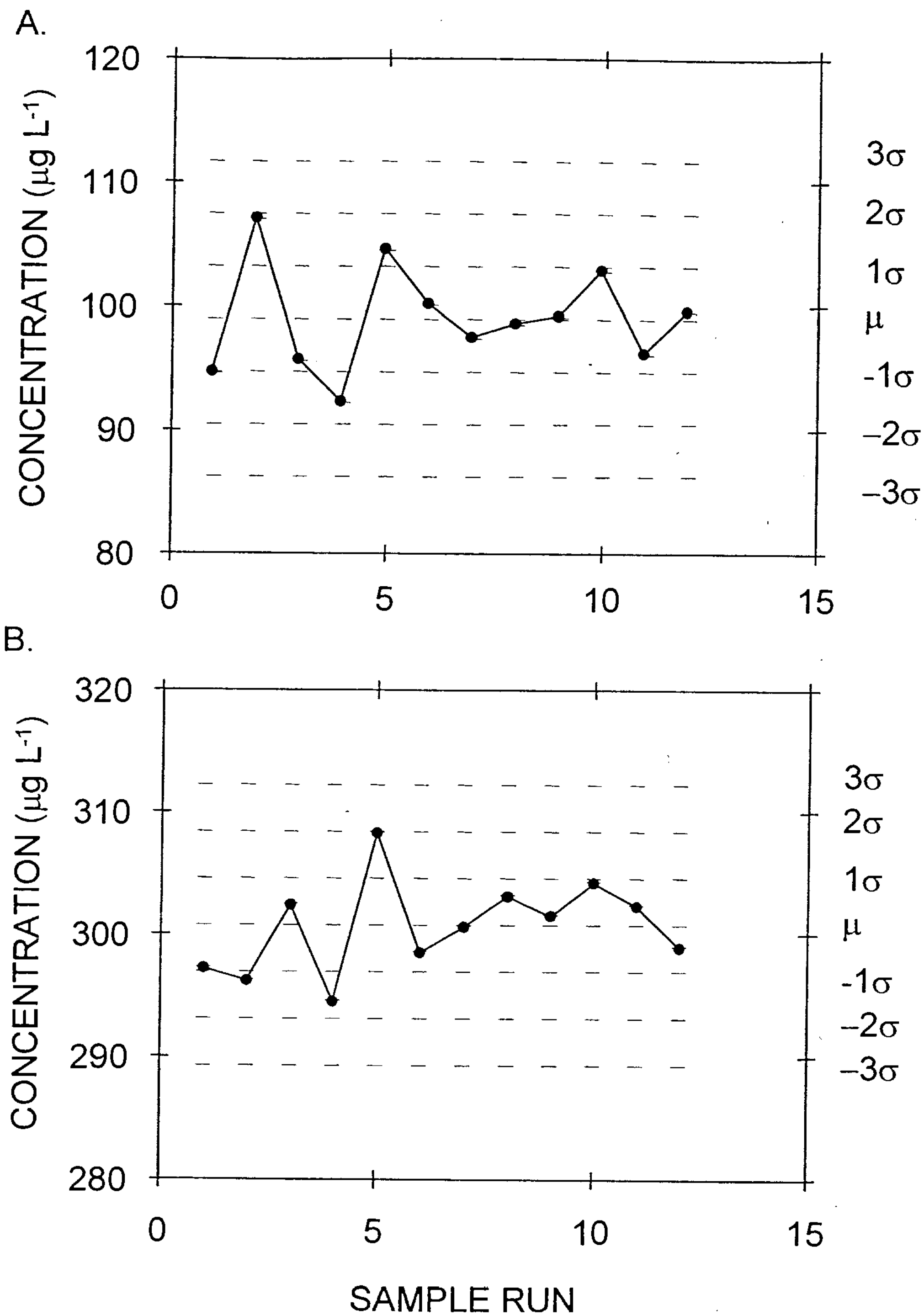

Figure 2. Control chart for Kjeldahl nitrogen standards at low (A) and high (B) concentration showing the mean (μ), inner control limit (±2σ) and outer control limit (±3σ).

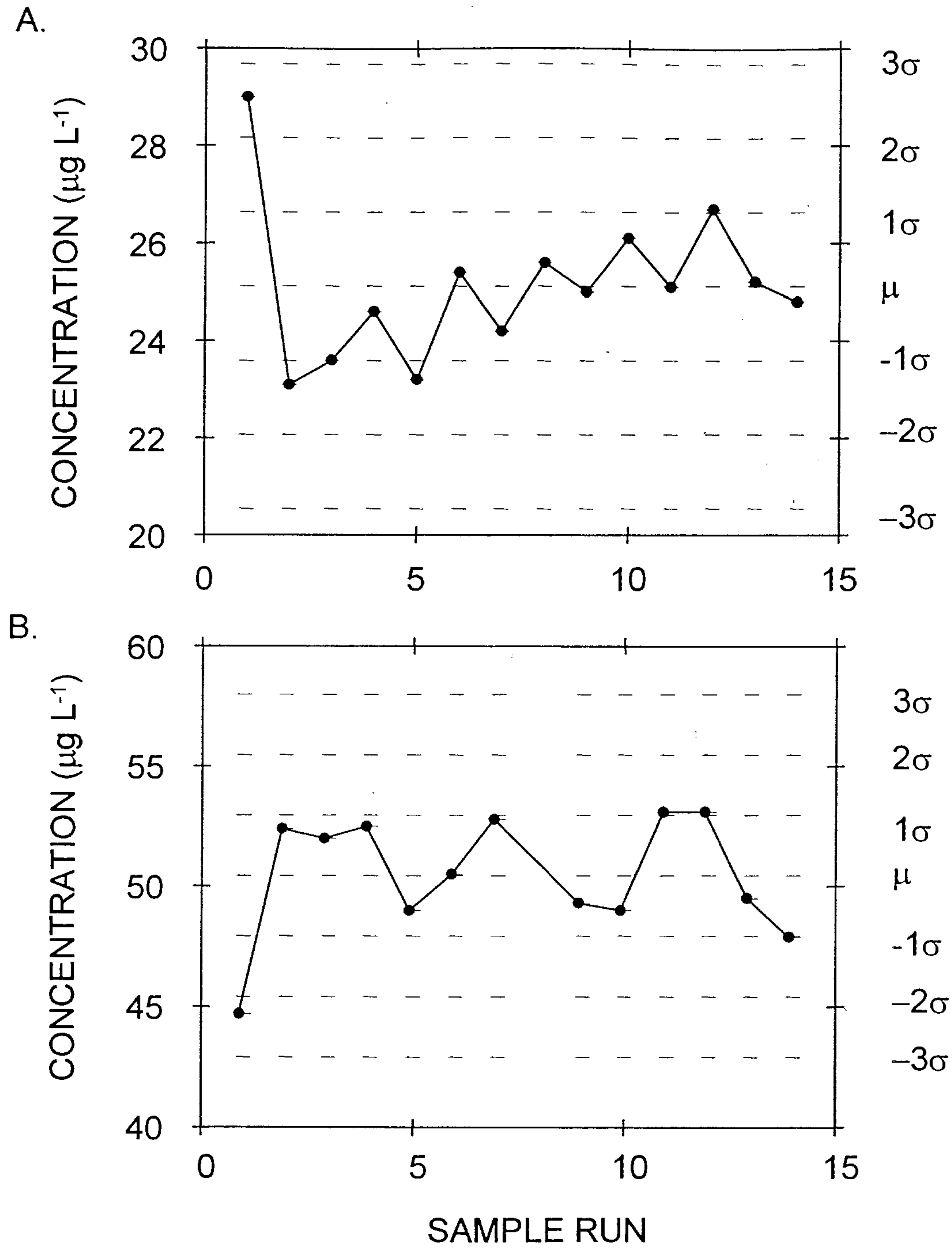

Figure 3. Control chart for ammonia standards at low (A) and high (B) concentration showing the mean (μ), inner control limit ($\pm 2\sigma$) and outer control limit ($\pm 3\sigma$)

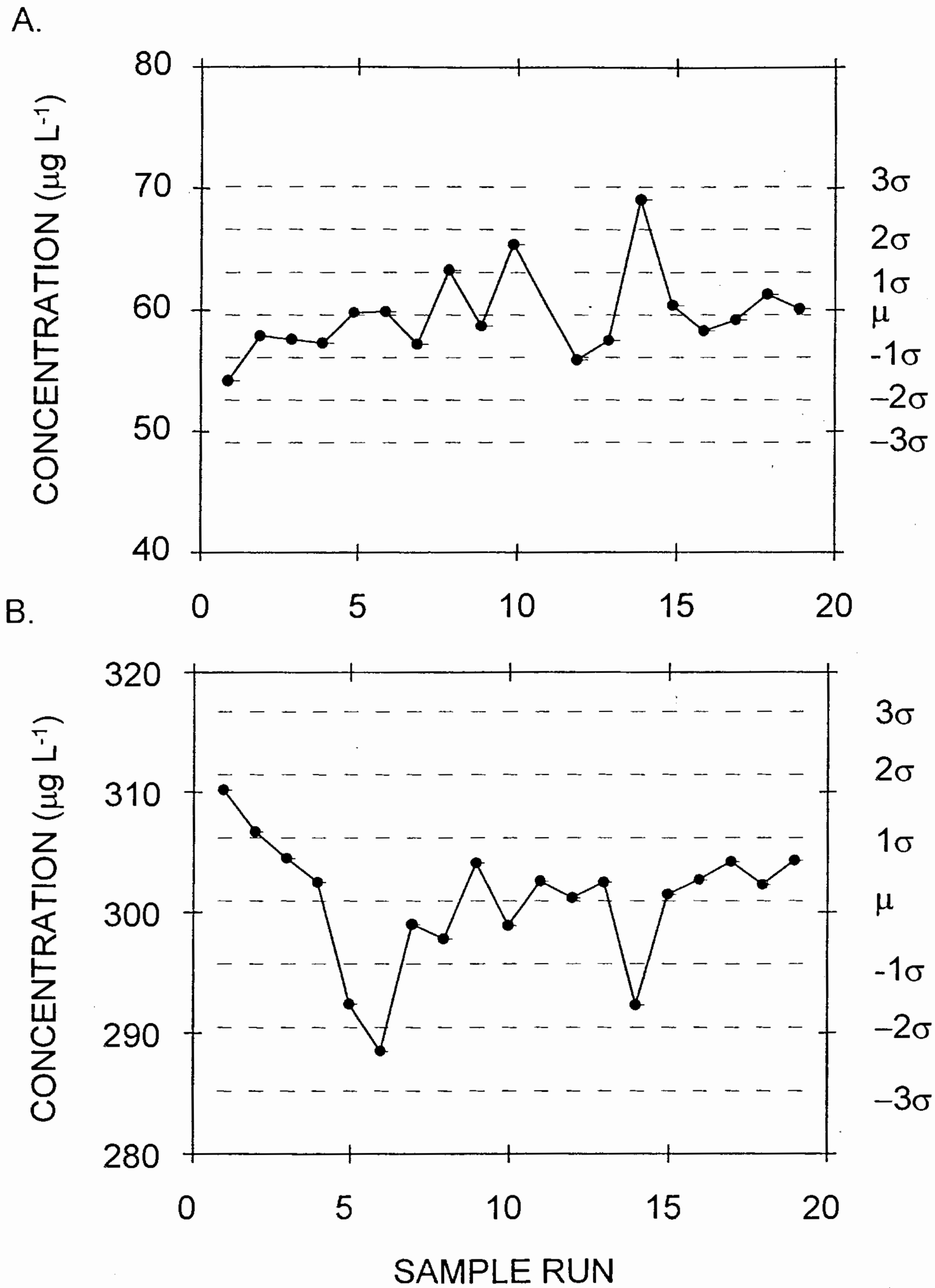

Figure 4. Control chart for nitrate standards at low (A) and high (B) concentration showing the mean (µ), inner control limit (±2σ) and outer control limit (±3σ).

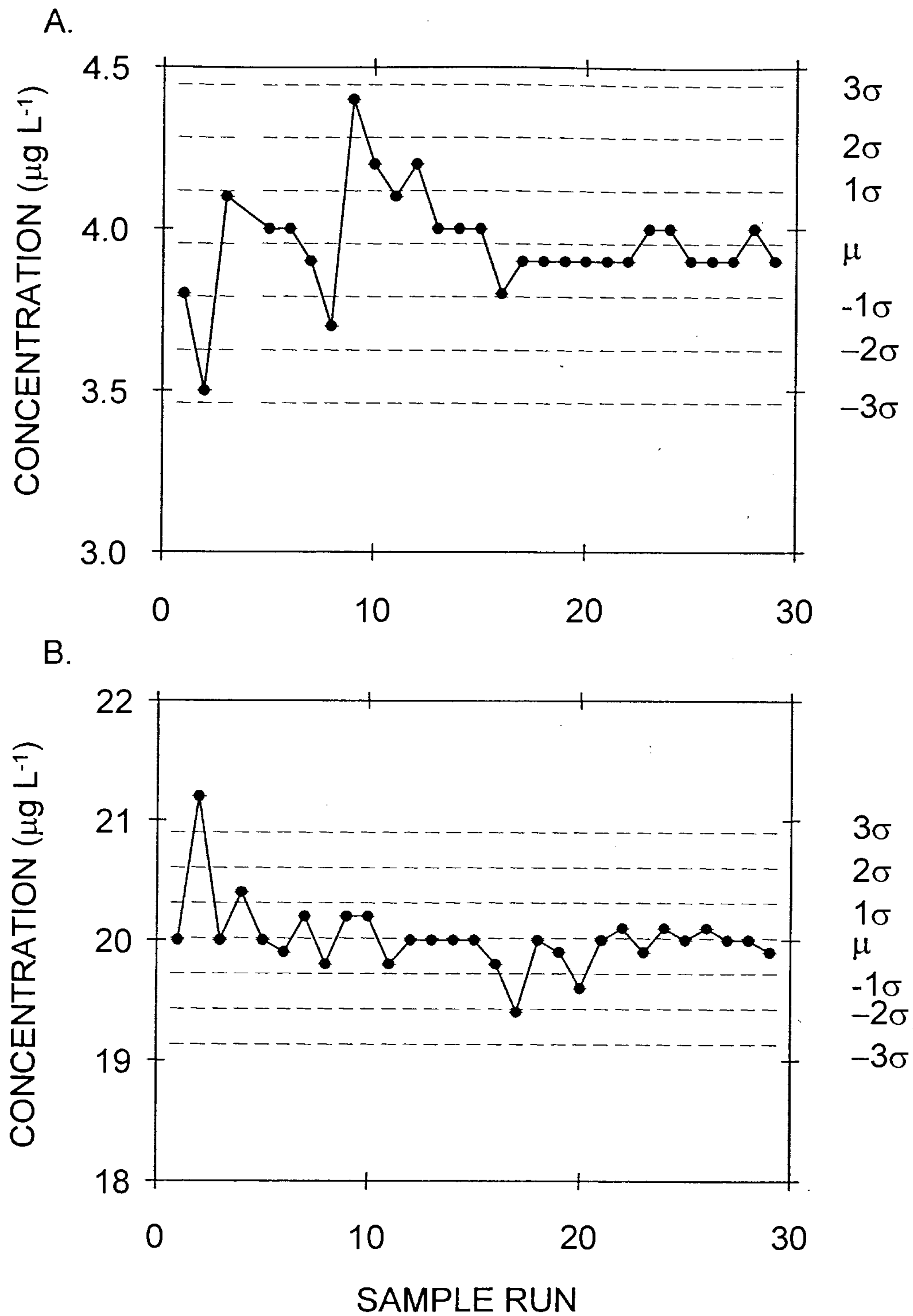

Figure 5. Control chart for total phosphorus standards at low (A) and high (B) concentration showing the mean (µ), inner control limit (±2σ) and outer control limit (±3σ).

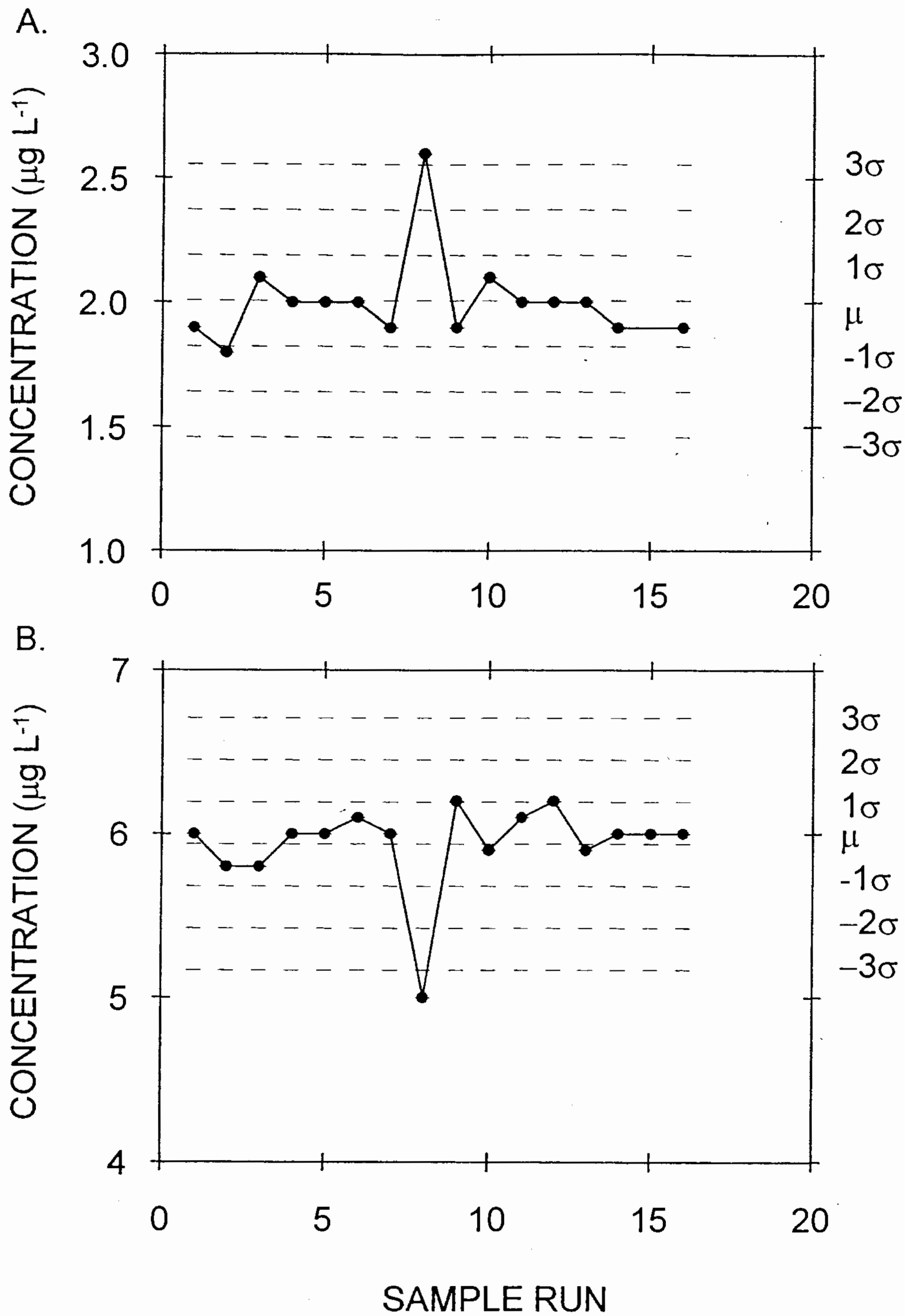

Figure 6. Control chart for filterable reactive phosphorus standards at low (A) and high (B) concentration showing the mean (μ), inner control limit (±2σ) and outer control limit (±3σ).

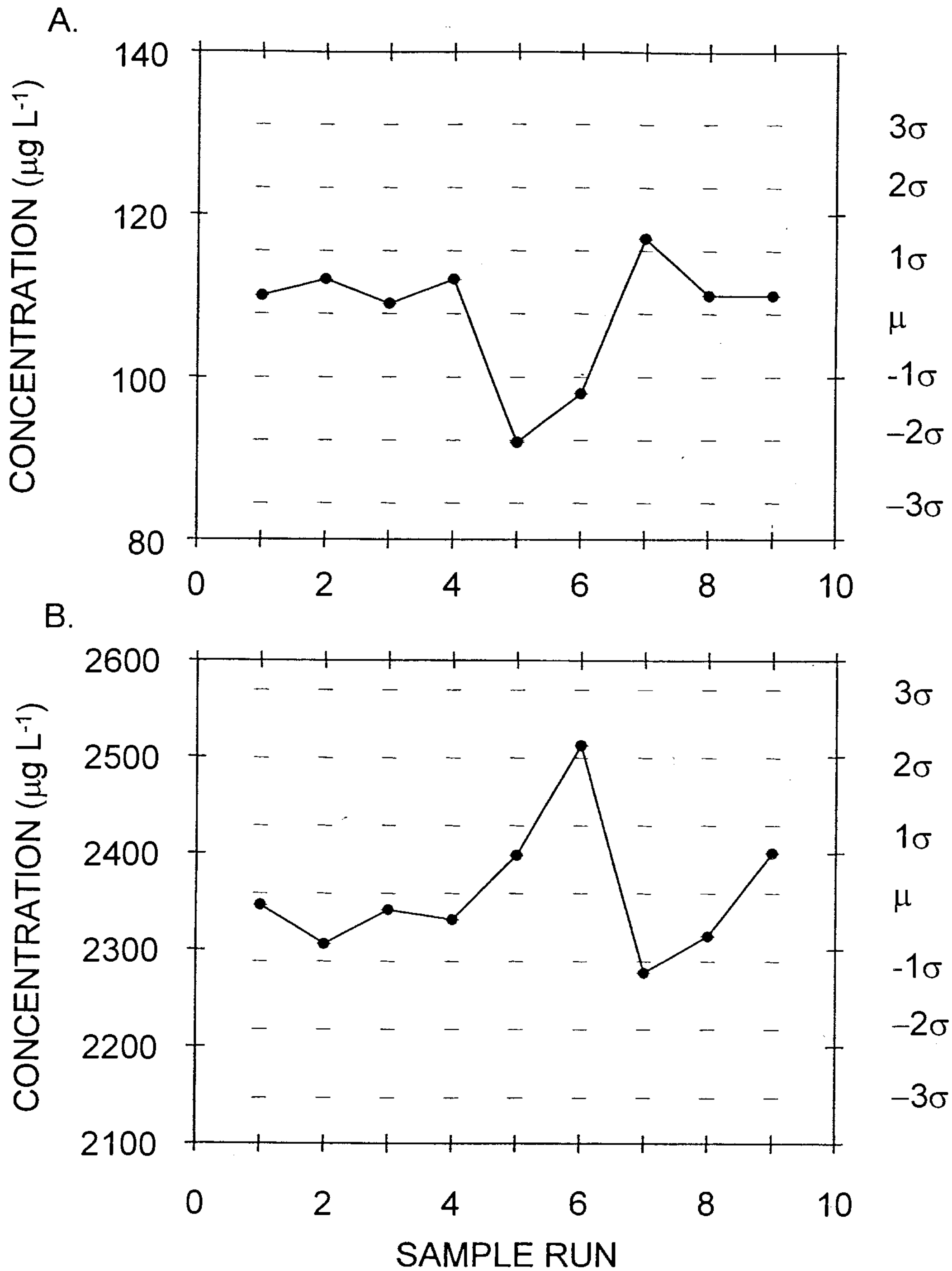

Figure 7. Control chart for reactive silicon standards at low (A) and high (B) concentration showing the mean (μ), inner control limit ($\pm 2\sigma$) and outer control limit ($\pm 3\sigma$).

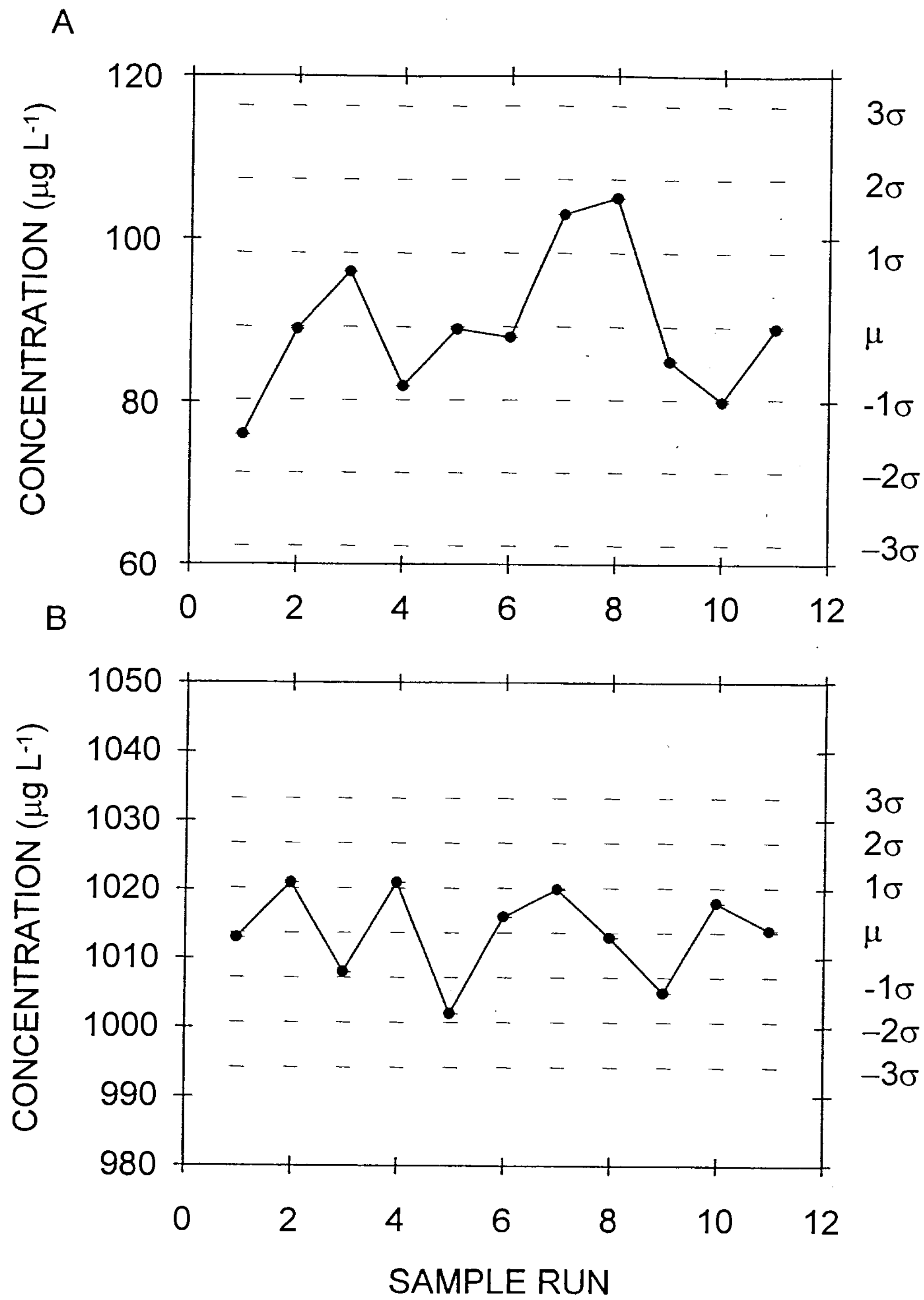

Figure 8. Control chart for total iron standards at low (A) and high (B) concentration showing the mean (μ), inner control limit ($\pm 2\sigma$) and outer control limit ($\pm 3\sigma$).

Table 4. Results from the 1999 U. S. Geological Survey Standard Water Reference Sample program showing the reference sample, constituents analyzed, reported value by Central Region Limnology (RV), most probable value (MPV)[\a], and rating[\b].

Reference Sample	Constituent	RV	MPV	Rating
N-63 (nutrients)	Ammonia nitrogen	0.129	0.150	2
	Kjeldahl nitrogen	0.210	0.200	4
	Nitrate + nitrite nitrogen	0.097	0.084	1
	Total phosphorus	0.161	0.158	4
	Filterable reactive phosphorus	0.142	0.144	4
N-69 (nutrients)	Ammonia nitrogen	1.400	1.380	4
	Kjeldahl nitrogen	1.570	1.540	4
	Nitrate + nitrite nitrogen	1.090	1.260	0
	Total phosphorus	0.904	0.883	4
	Filterable reactive phosphorus	0.860	0.860	4
P-33 (low ionic strength)	Calcium	0.468	0.043	0
	Magnesium	0.211	0.015	0
	pH	4.56	4.67	4
	Filterable reactive phosphorus	0.144	0.007	4
	Conductivity	20.8	20.8	4
M-48 (major consituents)	Silica	5.490	5.210	3
	Conductivity	387	380	4

a/ MPV is the statistic that represents the amount of analyte most likely present in the sample, based on test data.

b/ See text for explanation of rating.

routinely analyze multiple (usually 6-8) standards of known concentration with each sample lot and these are used to formulate a linear equation (calibration curve) by regressing absorbance against concentration. Consequently, the analytical results for nitrate nitrogen using our methodology are correct. On the other hand, our methodology for calcium and magnesium determination is not sensitive enough or appropriate for low-ionic strength samples. Together, both our internal and external quality control programs resulted in a high quality level of analytical work associated with accuracy and reproducibility. Table 5 presents the most recent evaluations of analytical methodologies used by CRL laboratory. This list of operating ranges, detection limits, and precision and accuracy replaces that found in Koenings et al. (1987).

RESEARCH PRODUCTS and PUBLICATIONS

The following is a list of research papers/reports that have been published or submitted for publication within the last year and their publication status. Also listed are research and technical findings presented by CRL staff at various professional symposia, seminars, workshops, and public forums.

Publications

Edmundson, J. A and G. L. Todd. 2000. Project operational plan: juvenile sockeye salmon assessment and limnological investigations of Lake Iliamna. Alaska Department of Fish and Game, Commercial Fisheries Division. Western Alaska Disaster Grant (WADG) project – funding by U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NA96FW0196).

Edmundson, J. A. and J. D. LaPerriere. 1999. A regional and hierarchical perspective of thermal regimes in subarctic, Alaksan lakes. *Freshwater Biology*. (In revision).

Edmundson, J. A. and J. D. LaPerriere. 1999. Linking growth of juvenile sockeye salmon to temperature in Alaskan lakes. *Transactions of the American Fisheries Society*. (In revision).

Edmundson, J. A., M. S. Dickson, and W. A. Bucher. 2000. Limnological and fishery investigations concerning sockeye salmon production in Delight and Desire Lakes, *Exxon Valdez* Oil Spill restoration Project Final report (Restoration Project 98254), Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Soldotna, Alaska (In revision).

Edmundson, J. A., V. P. Litchfield, and D. M. Cialek. 2000. An assessment of trophic status of 25 lakes in the Matanuska-Susitna Borough, Alaska. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report No. 2A00-26:41p.

Table 5. Statistical evaluation of analytical methodologies used by Central Region Limnology laboratory.

Parameter	Methodology	Lower limit of detection	Upper limit of detection	Precision	Accuracy (±)
Specific conductance	electrometric (compenstated @ 25° C)	0.1 μmhos cm	NA[a]	3% @ Full scale	5% @ Full scale
pH	electrometric	0.1 Unit	14 Units	1% @ pH Unit	3% @ pH Unit
Alkalinity	titration (0.02 N H_2SO_4)	0.6 mg L^{-1}	NA	3% @ 10 mg L^{-1}	7% @ 10 mg L^{-1}
Turbidity	nephelometric	0.01 NTU	### NTU	1% @ Full scale	1% @ Full scale
Color	absorbance 400 nm	3.0 Pt units	NA	NA	NA
Calcium	EDTA titration	0.2 mg L^{-1}	150 mg L^{-1}	6% @ 5 mg L^{-1}	4% @ 5 mg L^{-1}
Magnesium	EDTA titration	0.3 mg L^{-1}	175 mg L^{-1}	12% @ 3 mg L^{-1}	10% @ 3 mg L^{-1}
Total iron	colorimetric (HCl digestion)	11.2 μg L^{-1}	7000 μg L^{-1}	15% @ 100 μg L^{-1}	5% @ 100 μg L^{-1}
Reactive silicon	colorimetric (heteropoly blue)	20.4 μg L^{-1}	3000 μg L^{-1}	5% @ 700 μg L^{-1}	2% @ 700 μg L^{-1}
Kjeldahl nitrogen	colorimetric (block digestion, phenate)	4.6 μg L^{-1}	3000 μg L^{-1}	8% @ 100 μg L^{-1}	3% @ 100 μg L^{-1}
Total ammonia	colorimetric (phenyl hypochlorite)	1.7 μg L^{-1}	500 μg L^{-1}	4% @ 100 μg L^{-1}	2% @ 100 μg L^{-1}
Nitrate + nitrite	colorimetric (cadmium reduction)	4.1 μg L^{-1}	500 μg L^{-1}	6% @ 100 μg L^{-1}	1% @ 100 μg L^{-1}
Total phosphorus	colorimetric (persulfate digestion, molybdenum blue)	0.3 μg L^{-1}	1100 μg L^{-1}	6% @ 6 μg L^{-1}	3% @ 6 μg L^{-1}
Reactive phosphorus	colorimetric (molybdenum blue)	0.3 μg L^{-1}	1100 μg L^{-1}	5% @ 6 μg L^{-1}	2% @ 6 μg L^{-1}
Particulate organic carb	colorimetric (wet oxidation)	7.4 μg L^{-1}[b]	600 μg L^{-1}	7% @ 300 μg L^{-1}	3% @ 300 μg L^{-1}
Total particulate phosphorus	colorimetric (block digestion, molybdenum blue)	0.4 μg L^{-1}[b]	27 μg L^{-1}	6% @ 5 μg L^{-1}	7% @ 5 μg L^{-1}
Total particulate nitrogen	colorimetric (block digestion, phenate)	0.1 μg L^{-1}[b]	60 μg L^{-1}	4% @ 40 μg L^{-1}	3% @ 40 μg L^{-1}
Chlorophyll *a*	fluorometric	0.05 μg L^{-1}[b]	NA	13% @ 1.5 μg L^{-1}	12% @ 10 μg L^{-1}

a/ NA = not available/applicable.

b/ detection limit for in-lake concentration assumes volume of lake water filtered is 1.0 liter.

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Edmundson, J. A. 2000. Overview of Alaska's limnology program concerning sockeye salmon production. University of Victoria, Presentation to the Faculty of the Department of Biology, Victoria, BC. July 13, 2000.

Staff Development

Jim A. Edmundson was admitted into the doctor of philosophy program in biology at the University of Victoria, British Columbia. His proposed research scheduled to commence this fall is directed toward trophodynamics of sockeye salmon ecology in relation to stock and recruitment. Virginia Litchfield completed two courses in stream ecology at the Kenai Peninsula Community College, University of Alaska as part of her post-degree continuing education. John Edmundson, Gary Todd, Virginia Litchfield and Richard Dederick attended the ADF&G sponsored workshop on sonar technology and its application held in Soldotna. Virginia Litchfield participated in all public meetings of the Kenai River Water Quality Monitoring Coalition. All CRL staff received annual first aid/CPR certification.

ADDENDUM or ERRATA CONCERNING FIELD and LABORATORY MANUAL

Light Penetration

The following methods for calculating euphotic zone depth (EZD) and light extinction coefficient (K_d) replaces the methodology previously described in the Limnology Field and Laboratory Manual (Koenings et al. 1987).

The method presented in the Manual does not follow the theoretical model of underwater light extinction (e.g., Kirk 1994). The theoretical model is

$$I_Z = I_0 e^{-K_d Z}$$

where, I_Z = light extinction (µmol sec^{-1} m^{-1}) at depth Z
I_0 = light at subsurface
K_d = light extinction coefficient
Z = depth (meters).

The model can be re-written in a linear form as

$$\ln\frac{I_0}{I_Z} = K_d Z\,.$$

The predicted value of the following regression ($Y = \beta_0 + \beta_1 X + \varepsilon$) model can be used to estimate K_d from a set of photometer measurements; i.e.,

$$\ln\frac{I_0}{I_Z} = K_d Z + \varepsilon\,.$$

Note that this is a 0-intercept (no constant model), which adheres to the theory and insures that the predicted subsurface light is 100% of maximum. The parameter K_d (slope) can be estimated using simple linear regression analysis with a 0-intercept model specified. *EZD*, the depth that gives a predicted 1% subsurface light, is calculated by substituting ln(100) into the regression equation:

$$EZD = \frac{\ln(100)}{K_d} = \frac{4.60517}{K_d}.$$

Lake Heat Budgets

The method presented in the Manual for calculating the summer heat budget is incorrect. As written, following Steps 3 and 4 in the Manual produces a value equivalent to the average heat content over the growing season, not the summer heat budget. While the average heat budget is an index of heat content, it is not the standard heat budget variable used in the literature. The following method replaces that previously described by Koenings et al. (1987).

Partition the water column into several smaller increments (e.g., 1 to 5 m) where the change in temperature is ≥1° Celsius and courser increments (e.g., 10 to 20 m) when the temperature gradients are weak (≤1° Celsius). Obtain the mean temperature of a volume increment ($\bar{t}$) by computing the average temperature of the upper and lower boundary (depth) for the specified volume increment (v). Assuming a value of unity for density and specific heat, total the product of temperature and volume for each increment through the entire water column to give heat content and then divide the heat content (HC) by the lake surface area (A) as in the following equation:

$$HC \text{ (gram-calories cm}^{-2}\text{)} = A^{-1}\sum_{i=1}^{i=n} v\bar{t}_i$$

Where n is the number of volume increments. The difference in heat content between spring isothermy at 4° Celsius and maximum observed heat content is the estimated summer heat budget.

Zooplankton Weight and Biomass Estimation

Currently, zooplankton body length measurements are obtained on up to 15 specimens for a given species per sample. The arithmetic mean of these values ($\bar{L}$) is converted to mean weight ($\bar{W}$) using the conversion equation

$$\bar{W} = a\bar{L}^b$$

where a and b are parameter estimates from a regression analysis using measured dry weights for that species. The statistical model is

$$W = \alpha L^B e^v$$

where α and β are the model parameters and v is the error term. The problem is that " a mean raised to a power is not equal to the mean of the individual observations raised to that power" i.e.,

$$\left(\frac{\sum L}{n}\right)^b \neq \frac{\sum\left(L^b\right)}{n}.$$

The approach presented in the Manual of using density-weighted mean length to calculate seasonal mean biomass using the first equation is not the preferred method. Rather, predict (estimate) the weight of an individual zooplankter using the appropriate length-weight conversion as given in the Manual

$$\hat{W} = aL^b.$$

Then estimate mean weight of a species using

$$\hat{\bar{W}} = \frac{\sum \hat{W}}{n}$$

where n is the number of specimens (per species) measured.

Finally, estimate biomass (*BIOM*) of each species in the sample by expanding the mean weight estimate by the density (D)

$$BIOM = \hat{\bar{W}}\left(\hat{D}\right).$$

Note: results using the new approach do not differ greatly from the old approach so that previous results are not necessarily "wrong". The new method simply avoids the problem of small (~6%) negative bias associated with the calculations as presented in the Manual (Koenings et al. 1987).

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